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Assessment of Heavy Metals Pollution in Soils and Vegetation around Selected Industries in Lagos State, Nigeria

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Abstract

In this study, eleven soil samples and twenty-twoplants samples were collected in the vicinity of eleven industries and a thermal station was analyzed for zinc, copper, iron, lead and cadmium. Soil sample from Egbin thermal station had the highest concentration of Zn (141.06 mg/kg) and Cu (131.70 mg/kg). Soil from international textile had the highest level of Fe and the soil from Nichemtex had the highest concentration Pb and Cd was the highest in soil from Guinness (28.91 mg/kg, 59.80 mg/kg and 1.72 mg/kg respectively). The highest concentrations of the heavy metals were observed from different plants species. Analyses of variance ($p < 0.05$) showed that heavy metal variation in plant and soil samples were not significant ($p > 0.5$). There were positive correlations between the heavy metals in the soils and the plant samples indicated that the plants obtained the heavy metals from the soil. Plants having BCF values less than one had limited ability to accumulate, translocate and phytoextract heavy metals. These plants in this study with higher Bioconcentration Factor value especially those greater than one (*Croton lobatus*, *Borreria sp.*, *Cyathula prostrata*, *Lantana camara*, *Ficus sp.*, *Mimosa pudica*, *Eclipta prostrata*, *Commelina sp.* etc.) were suggested for further research and assessment on their bioaccumulation abilities and phytoremediation potential.

Keywords

Heavy Metals, Bioaccumulation, Industries, Phytoremediation

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1. Introduction

Fifty percent of Nigeria's industrial activities including 300 industries in 12 industrial estates are located in the Lagos area [1]. The high urbanization and industrial growth rate in Lagos had made it one of the most densely populated regions on the earth with a population of about 9.3 millions according to 2006 Census [2]. Thus, the continuous increase in population and industrial growth in Lagos persistently cause large volume of wastes to be generated industrially and domestically [1]. Industries have largely been responsible for discharging untreated effluents containing trace metals such as zinc (Zn), copper (Cu), manganese (Mn), cadmium (Cd), mercury (Hg), nickel (Ni), lead (Pb), Iron (Fe) and Chromium (Cr) improperly into our environments [3]-[5]. Soils and plants in nearby zone of industrial areas display increased concentration of heavy metals, serving in many cases as sinks of pollution loads [6]. Plants around industries take up large quantities of pollutants which they translocate into vegetative and generative organs at various rates [7] [8]. However, pollution in developing nations is correlated with the degree of industrialisation and the intensity of chemical usage [9]-[11].

The concentrations of heavy metals in animals have harmful effects especially when consum above the bio-recommended limits from plants [12]. Although individual metals exhibit specific signs of their toxicity, the followings have been reported as general signs associated with cadmium, lead, iron, zinc, and copper poisoning: gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremor, hemoglobinuria causing a rust-red colour to stool, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia when volatile vapours and fumes are inhaled [13]. The nature of effects can be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic [12].

The overall objective of this study is to investigate the influence of industrial activities and associated processes with heavy metal contamination of soils and vegetation in Lagos city, and comparing heavy metal contents in soils and that of the plants (Bioaccumulation). Information being obtained can assist in identifying and subjecting bioaccumulators for remediation of polluted soils.

2. Materials and Methods

2.1. Study Area

Study areas included three local government areas in Lagos, south western Nigeria (**Figure 1**). It is Nigeria's largest city, chief port, and principal economic, cultural and industrial center.

Figure 1. Map of Lagos (in Nigeria) showing sampling locations.

2.2. Description of Sampling

All the sites are located within Lagos metropolis in Lagos state is shown in **Figure 1**. The different sampling sites, the locations and products of industries are shown in **Table 1**.

2.3. Sample Collections

Samples of soils and plants were collected in the month of June, July and August 2012. Twenty-two (22) plant samples and eleven (11) soil samples were obtained from Ikeja, Ikorodu and Alimosho Local government areas (**Figure 1**). The soil samples were collected at depth ranging between 5 - 25 cm using a steel soil auger and kept in a tagged polythene bags. The plants were carefully uprooted and also labelled in designated polythene bags [14].

2.4. Plant Samples Digestion and Analyses

Each plant sample was separated into leaf, stem and root. Each part was cut into pieces and air-dried; each plant part was further dried in an oven at 80˚C, milled with an electric blender into powdery consistency. Each milled plant part samples was mixed properly by rumbling and sieved through (1 mm) mesh filler [14].

A gram of each milled homogenized sample was weighed with a digital weighing balance in to a conical flask. 5 ml of 60% hydrochloric acid (HCl) and 10 ml of 70% nitric acid (HNO_3) were added into the weighed samples. The sample mixture was digested with a moderate heat (50˚C) with a hot-plate until white fumes evolved, makingit brownish solution. The heat was intensified further for few minutes to expel off most of the hydrochloric acid (HCl). 50 ml of distilled water was dispensed into the solution and heated for a few minutes, allowed to cool before it was filtered through whatman's No 1 paper (11 µm) into a dispensed transparent plastic container that has been cleaned with detergent and treated successively with HCl and rinsed with deionized water. The filtered sample was left to stand for few minutes for the aspiration of the element according [15]. The digested samples were analyzed for zinc (Zn), lead (Pb), iron (Fe), copper (Cu) and cadmium (Cd) concentrations using atomic absorption spectrophotometer (AAS) [15].

2.5. Soil Samples Preparation and Analyses

The soil samples were air-dried and sieved to <0.25 mm, then stored in desiccators prior to analysis of heavy metals. 0.5 g of the dry sample was weighed and digested with a mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) as was described by [16]. 2 g sample was transferred to a Teflon beaker and 25 ml of distilled water was added. 2 ml of concentrated HNO_3 was added the contents of the beaker and this was allowed to evaporate to dryness. Subsequently, three drops of concentrated sulfuric acid (H_2SO_4) and 10 ml of hydrogen fluoride (HF) were added. The sample was then placed on a sand bath while the temperature slowly increased to 200˚C and was allowed to evaporate to dryness. This was followed by the addition of 15 ml of concentrated

Table 1. The different sampling sites, localized industries, their products with the gps coordinates.

s/n	Local Govt Area	Locations	Sites	Products	Coordinates
1.	Ikorodu	Odonla	International Textiles	Textiles	6.68016N/3.53359E
			Chikki/Holdent Industries	Paste, liquid wash, noodles	6.6778N/3.53899E
		Odogunyan	Sunflag Group (Spintex)	Steels, fabrics and textiles	6.67244N/3.52195E
			AKS Steel	Steel	6.66786N/3.52013E
		Losi Oba	Pzcusson	Soaps, detergents, cream	6.6738N/3.51897E
		Ijede	Egbin Thermal Station	Electricity by steam turbine	6.5632N/3.6152E
		Ibeshe	Nichemtex Textiles	Textiles and fabrics	6.69283N/3.13634E
2.	Ikeja	Oregun	7Up Bottling Company	Bottled carbonated drinks	6.63128N/3.22528E
		Alausa	Clay Industry Ltd.	Processed and kilned bricks	6.60729N/3.35658E
		Oba Akran	Guinness Plc.	Malted drinks and beer.	6.373584N/3.204066E
3	Alimosho	Kola	Chemstar Industries	Paints, wood finish and vanish	6.67603N/3.27039E

HNO_3, 2 ml of H_2SO_4, and 5 ml of $HClO_4$. Heating continued until strong fumes of SO_3 were produced. The Teflon container was cooled and the solution transferred quantitatively to a 50 ml volumetric flask by adding distilled water [16]. The concentrations of Zn, Pb, Fe, Cu and Cd, were determined by atomic absorption spectrophotometer [16].

2.6. Bioconcentration Factor (BCF)

Bioconcentration factor was calculated from the following equation as described by [17].

$$\text{BCF} = \frac{\text{Concentration of heavy metal in plant}}{\text{Concentration of heavy metal in soil}}$$

2.7. Statistical Analyses

The descriptive statistical parameters were calculated with Graph Pad Prism software package (version 6.0), the correlations of heavy metals in soils and plants were analyzed using Pearson correlation analysis. One-way analysis of variance (ANOVA) was performed to test the significance of differences in total metal concentrations in plant and soil samples. The Tukey-Kramer Multiple Comparisons Test was used to compare all heavy metal concentration levels in soils and plant.

3. Results

3.1. Heavy Metal Concentration in Soil Samples

The metal concentration level in soil samples is shown in **Table 2**. The soil sample from the vicinity of Egbin power thermal station has the highest concentration of zinc (141.06 mg/kg) while the least was in the soil sample from Clay industry (6.23 mg/kg). There was no significant difference ($p > 0.05$) in the concentration of zinc in all soil samples and they were all below the standard threshold value (EU/UK/USEPA threshold). The concentration of copper in the soil samples varied from 0.93 mg/kg in the vicinity of Chikki/Holdent Industries to 131.70 kg/mg in the soil from Egbin power thermal station. There was no significant difference ($p > 0.05$) in copper concentration in all soil samples. Concentration of iron in soil samples was the highest in soils at International Textile Limited (28.91 mg/kg) and least in Nichemtex industries (1.201 mg/kg). There was significant difference ($p < 0.05$) among iron concentration from all the different soil samples. Lead concentration in sampled soils range from 1.12 mg/kg in the vicinity of Clay industries to 59.80 kg/mg in Nichemtex industries. There was no significant difference ($p > 0.05$) in lead concentration in all soil samples analysed. The concentration of

Table 2. Heavy metal concentration in soil samples (mg/kg).

S/n	LocalGovt	Location	Sites	Zn	Cu	Fe	Pb	Cd
1.	Ikorodu	Odonla	International Textile	19.58	40.20	28.91	32.58	0.27
			Chikki/Holdent Industries	14.32	0.93	27.12	9.98	0.19
		Odogunyan	Sunflag Group (Spintex)	41.62	5.38	21.11	44.09	0.022
			AKS Steel	39.87	20.07	16.71	2.09	0.016
		Losi Oba	Pz Cusson	49.21	18.21	4.82	18.10	0.019
		Ijede	Egbin Thermal Station	141.06	131.70	12.90	3.12	0.20
		Ibeshe	Nichemtex	46.12	34.12	1.201	59.80	0.178
2.	Ikeja	Oregun	7up Bottling Company	17.46	9.09	1.782	1.60	ND
		Alausa	Clay Industries	6.23	22.08	6.04	1.12	ND
		Oba Akran	Guinness Plc	12.10	31.11	1.77	2.02	1.72
3.	Alimosho	Kola	Chemstar	54.11	32.06	14.12	29.27	0.15
	Standard Threshold Value		EU Threshold Value	300	130-140	NA	300	3.0
			USEPA Threshold Value	300	80-200	NA	300	3.0
			UK Threshold Value	100-200	63	NA	70	1.4

cadmium in soil sampled vary from zero (not detected) in some locations to 1.72 mg/kg in the vicinity of Guinness in Ikeja. There was significant difference ($p < 0.05$) in the concentration of cadmium in the soil samples. However, cadmium concentrations were all below the threshold values (EU/UK/USEPA threshold) for the heavy metal in soil. Analyses of variance show variation among heavy metals in soil samples to be significant ($p < 0.5$).

3.2. Heavy Metal Concentration in Plants

The metal concentration level of heavy metals in plant samples is shown in **Table 3**. The highest concentration of copper was recorded in *Borreria sp*. (151.50 mg/kg) with the least in *Amaranthus spinosus* (0.1 kg/mg). There was significant difference ($p < 0.05$) in copper concentration across all the plant samples. Zinc concentration level in plant samples range from 2.20 mg/kg to 19.18 mg/kg with *Croton lobatus* having the highest concentration while *Cyathula prostrata* had the least. However, there was no significant difference ($p > 0.05$) in zinc concentration level in 75% of all sampled plants. Iron concentrations range from 0.41 mg/kg in *Ludwigra sp*. to 38.01 mg/kg in *Ficus sp*. and there was significant difference ($p < 0.05$) in all plant samples. The highest concentration of lead was recorded in *Corchorus oliterus* (3.19 mg/kg) and the least in *Cyathula prostrata* (0.59 mg/kg) and there was no statistical difference ($p > 0.5$) across all plants. Concentrations of cadmium in plant was generally low varying from zero in so many plants to 0.02 mg/kg and were quite below the threshold values (EU/UK/ USEPA threshold) for heavy metals in plants.

Table 3. Heavy metal concentration in plant samples (mg/kg).

s/n	Plant Name	Zn	Cu	Fe	Pb	Cd
1	*Ipomea sp.*	4.11	12.10	11.22	2.91	0.02
2	*Ficus sp.*	3.10	1.14	38.01	1.06	ND
3	*Panicum sp.*	3.52	3.01	28.01	1.48	ND
4	*Alchornia cordifolia*	2.44	4.12	1.89	3.05	ND
5	*Panicum maximum*	5.08	0.16	6.11	0.63	ND
6	*Commelina africana*	11.6	0.94	17.04	1.58	ND
7	*Commelina sp.*	8.11	1.22	16.20	0.71	ND
8	*Amaranthus spinosus*	3.12	0.10	0.881	2.98	ND
9	*Solanum lycopersicum*	2.88	0.98	0.691	0.99	ND
10	*Borreria sp.*	9.14	151.50	17.77	1.68	0.005
11	*Mimosa pudica*	3.99	98.16	11.70	0.58	0.010
12	*Chromolena odorata*	3.01	52.34	6.70	0.72	0.012
13	*Lantana camara*	6.12	10.03	16.92	0.62	ND
14	*Eclipta prostata*	6.31	0.28	1.612	0.71	ND
15	*Althernathera sessilis*	8.28	0.94	1.110	0.82	ND
16	*Laportea aestuarns*	5.31	0.88	1.12	0.61	ND
17	*Cyathula prostrata*	2.20	0.262	11.67	0.59	ND
18	*Tridax procumbens*	3.22	2.56	1.56	0.91	ND
19	*Corchorus oliterus*	8.96	0.22	1.141	3.19	0.012
20	*Sacciolepis africana*	19.18	1.213	1.01	4.09	ND
21	*Ludwigia sp.*	22.20	22.28	0.41	1.65	ND
22	*Croton lobatus*	23.00	71.60	1.89	2.71	ND
	WHO/FAO GUIDELINES	60.0	30	48.0	2	1.0
	NAFDAC	50.0	20	NA	2	NA
	EC/CODEX	NA	0.3	NA	0.3	0.2

ND-Not Detected.

3.3. The Bioconcentration Factor (BCF)

The bioconcentration factor is shown in **Table 4**. BCF value is highest in copper than in any other heavy metals. For copper the BCF values ranged from 0.012 to 2.099, zinc from 0.021 to 0.500, iron from 0.080 to 1.574, in lead from 0.029 to 0.538 and cadmium from 0.00 to 0.080. *Croton lobatus* had the highest bioaccumulation for Zn and Cu with BCF value of 0.500 and 2.099 respectively, *Cyathula prostrata ha*s the highest bioaccumulation for Fe and Pb with BCF value of 1.932 and 0.527 respectively, while *Corchorus oliterus* has the highest BCF value of 0.080 for Cd.

3.4. Correlation between Metals in Soil and Plant Samples

Correlation between metals in plant and soil samples is shown in the **Table 5**. Thecorrelation between soil and plant for all the metals are all positive. These relations were significant for copper, iron, lead and cadmium (r = 0.718, r = 0.644, r = 0.705 and r = 0.010 respectively) but not significant for zinc (0.030). The correlation pattern indicates that the heavy-metal concentrations of Cu, Fe, and Cd in plants are associated with the concentration in

Table 4. Bioconcentration factor of Zn, Cu, Fe, Pb and Cd.

S/N	Plant Name	Zn	Cu	Fe	Pb	Cd
1	*Ipomea sp.*	0.209	0.301	0.388	0.089	0.074
2	*Ficus sp.*	0.158	0.028	1.314	0.033	0.000
3	*Panicum sp.*	0.180	0.075	0.970	0.045	0.000
4	*Alchornia cordifolia*	0.125	0.103	0.038	0.094	0.000
5	*Panicum maximum*	0.355	0.170	0.226	0.063	0.000
6	*Commelina africana*	0.279	0.175	0.807	0.036	0.000
7	*Commelina sp.*	0.203	0.061	0.969	0.339	0.000
8	*Amaranthus spinosus*	0.063	0.006	0.183	0.165	0.000
9	*Solanumly copersicum*	0.059	0.054	0.143	0.055	0.000
10	*Borreria sp.*	0.065	1.150	1.377	0.538	0.025
11	*Mimosa pudica*	0.028	0.745	0.907	0.186	0.050
12	*Chromolena odorata*	0.021	0.397	0.519	0.231	0.060
13	*Lantana camara*	0.013	0.076	1.312	0.199	0.000
14	*Eclipta prostate*	0.361	0.031	0.905	0.444	0.000
15	*Althernather asessilis*	0.474	0.103	0.623	0.513	0.000
16	*Laportea aestuarns*	0.304	0.097	0.628	0.381	0.000
17	*Cyathula prostrata*	0.353	0.012	1.932	0.527	0.000
18	*Tridax procumbens*	0.266	0.082	0.881	0.450	0.000
19	*Corchorus oliterus*	0.166	0.007	0.080	0.109	0.080
20	*Sacciolepis africana*	0.416	0.036	0.841	0.068	0.000
21	*Ludwigra sp.*	0.481	0.653	0.341	0.028	0.000
22	*Croton lobatus*	0.500	2.099	1.574	0.045	0.000

Table 5. Computed pearson correlation between heavy metals in plant and soil samples.

Correlation between metals	Correlation coefficient value
Zinc in soils and plants	0.030
Copper in soils and plants	0.718*
Iron in soils and plants	0.644*
Lead in soil and plants	0.705*
Cadmium soil and plants	0.010*

the soils but Zn might be influenced by other unknown sources.

4. Discussion

High values of copper observed generally in this study are consistent with values reported by [18] [19]. They identified plants to greatly uptake Cu, Cd and Zn. Cu exhibited considerable variations from location to location with the highest value observed at Egbin thermal station although still within the range of International threshold values for copper concentration in soils. Comparison of the Cu concentration in all sampled plants showed that it is higher in plants located in the vicinity of the thermal station. Melting, grinding or the cutting of copper, and emission from electricity cables, may produce fumes and dust, and exposure or inhalation of these fumes may produce potential health hazards [20]. Fumes of copper may cause metal fumes fever with flu-like symptoms and hair and skin discoloration in man although dermatitis has not been reported, it can also cause irritation of the upper respiratory tract, a metallic taste in the mouth and nausea [20]. [21] [22] explained that there are different tolerance ranges for plants, but a critical toxic level of Cu is in the range of 20 - 30 mg/kg for most plants. The risk of Cu toxicity in vegetation species is clearly evident by the fact that higher concentrations have been reported in this current study.

Cadmium is a toxic element and can cause serious health problems. The most common sources for cadmium in soil and plants are phosphate fertilizers, non-ferrous smelters, lead and zinc mines, sewage sludge application and combustion of fossil fuels [23] [24]. International threshold values for heavy metals concentration in soils for cadmium in soil are between 1.40 - 3 mg/kg [25]. At this level, in most cases, it is taken up metabolically and is easily transported to the other parts of the plant [26]. In this present study, Cd concentrations in all soil and plant samplesinvestigated in this presentstudy are low as also observed by [20].

Zinc is essential element for plant growth, as it serves an important role in plant structure and function [27], it is a natural constituent of soils in terrestrial ecosystem and it is taken up actively by roots [28]. In this study, there is slight pollution of Zn in the textile, paint and the thermal station with the highest concentration observed in soil of Egbin thermal station. The high concentrations of the soil could have negative effects on soil microbial population and activities [29], provoking a low organic matter mineralization during the plant growth. These results are line with the findings of [30] which observed the soils of Industrial area to be slightly polluted with Zn.

Iron is another essential element for plant and animalgrowth. Its deficiency can cause various types of diseases; however, its high concentration also affects plant growth. Iron concentration levels in soil samples collected from all locations showed no significantdifferences with the heavy metals in plants of same sites. However, the observed concentrations of Fe in plants are slightly higher than those in soils and none is beyond the regulated standards.

Lead is regarded as highly hazardous for plants, animals and particularly for microorganisms. The main sources of lead pollution in agriculture and plants are lead mines, combustion of leaded hydrocarbon, sewage sludge applications and farmyard manure, industrial processes etc. [20]. In this study the concentration Pb in 25% of the plants were higher than the maximum acceptable range of 0.3 - 2.0 mg/kg for plants. The highest concentrations of Pb in soils were observed in Sunflag group (spintex) and Nichemtex. The concentration of Pb in soil is of a significant interest as it is far higher than what [30] recorded in a similar study in the vicinity of Sunflag group (spintex). These high concentrations of Pb in soils indicate high amount of Pb in textile effluents. This result is in line with the findings of [30]-[32].

Plant species, physiological stage, uptake capability as well as growth rate are major determinants of metal transfer from soil to the crop [6]. The ability of plants to tolerate and accumulate these metals may provide the bases for their phytoremediation usefulness. Bioconcentration factor (BCF) can be used to assess a plant's potential for phytoremediation purposes. The highest BCF value for Zn and Cu was observed in *Croton lobatus*, for Fe it was observed in *Cyathula prostrata*, for Pb it was observed in *Borreria sp.* while *Corchorus oliterus* had the highest BCF for Cd.

In an attempt to understand the relationship between the concentrations of corresponding metals evaluated from the soil and plant samples, the Pearson Correlation Co-efficient, *r*, was used. There are positive correlation between soil and plants for all the metals in all the investigated areas. These relations were significant ($p < 0.05$) for Cu, Fe, Pb and Cd but not significant for Zn under the current study. The results of positive correlation between soil and plants have been supported by earlier research findings by [33] [34]. These positive relations indicate that plants take in nutritional elements from the soil through their roots. However, the negative correlation

relation indicated by Zn, give a strong suspicion to the fact that some elements might be assimilated through other organs of the plants other than their roots. Such elemental intake may be directly through atmospheric deposition.

5. Conclusion

The findings in this study show that plants in the vicinity of industries have high risk of having heavy metal concentrations beyond the permissible limit if safety and environmental law are not enforced. This study confirms a relationship between the concentration of heavy metals in the plants and soils. Plants having BCF values less than one had limited ability to accumulate, translocate and phytoextract heavy metals (Fitz and Wenzel, 2002). Therefore, we recommend plants in this study with higher BCF value especially those greater than one (such as *Croton lobatus*, *Borreria sp*., *Cyathula prostrata*, *Lantana camara*, *Ficus sp.*, *Mimosa pudica*, *Eclipta prostrata*, *Commelina sp*. etc.) be subjected for further research and assessment on their phytoremediation abilities.

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